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Integrated field intensity of atmospherics and related premonsoon thunderstorms

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Integrated field intensity of atmospherics (IFIA) associated with local premonsoon thunderstorms over a tropical station Calcutta have been studied simultaneously at 10 and 20 kHz. Important results obtained are :

(i) Generally, there are three stages of enhancement of an IFIA. These are (1) gradual rise of atmospherics (GRA), (2) first sudden enhancement of atmospherics (SEA_1) and (3) second sudden enhancement of atmospherics (SEA_2). Their respective occurrences have been found to be prevalent in pre-noon, late noon and afternoon hours of the day.

(ii) Out of the three stages of an enhancement, GRA and SEA_1 have been found to occur before the onset of thunderstorm in all cases while SEA_2 may even occur after the onset of thunderstorm. Moreover, SEA_2 has been found to be closely related to local precipitation.

(iii) Amplitude variations of GRA, SEA_1 and SEA_2 as well as that of the steady recovery of the IFIA have been found to be frequency dependent.

1. Introduction

It is well known that premonsoon thunderstorm popularly known as nor'wester causes the main weather hazard in Gangetic West Bengal. The hazards manifest themselves in the form of heavy turbulence, lightning, hail and squalls. In its process of development, it builds up from small detached cumulli to cumulonimbus which then culminates in a full fledged thunderstorm. Several investigations have been made on its occurrence and development from time to time (Koteswaram & Srinivasan 1958, Srinivasan 1960, Chaudhury & Rakshit 1970, Ray & De 1971). Close association of the integrated field intensity of atmospherics (IFIA) with nor'wester was reported earlier by one of the authors (Sen 1965, 1967) on LF band at 30 kHz, while investigations in the VLF bands are yet lacking. We are, therefore, interested to make a detailed study of IFIA observed over the tropical station Calcutta (lat. 22°34'N, long. 88°24'E) on two VLF

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bands, 10 and 20 kHz, in relation to premonsoon thunderstorms with a view to explore the role of cumulonimbus structure and its associated precipitation of IFIA. This has its importance for timely warning about the onset of nor'wester from the records of IFIA and it is considered most essential for hazardless aviation.

2. Observation and Typical Records

The straight tuned receivers employed for recording the IFIA were constructed with some modifications of the designs adopted by Ellison (1955). From a careful study of our daily records to the occasions of premonsoon thunderstorms reported from the local meteorological office and also as noticed over the observatory it has been found that, in general, there occurs an enhancement in IFIA at three different stages which are—gradual rise of atmospherics (GRA), first sudden enhancement of atmospherics (SEA_1) and the second sudden enhancement of atmospherics (SEA_2). A steady recovery of atmospherics (SRA) follows the sudden enhancement in all the cases and finally regains the normal level. Figure 1 represents two typical records of IFIA at 10 and 20 kHz during a

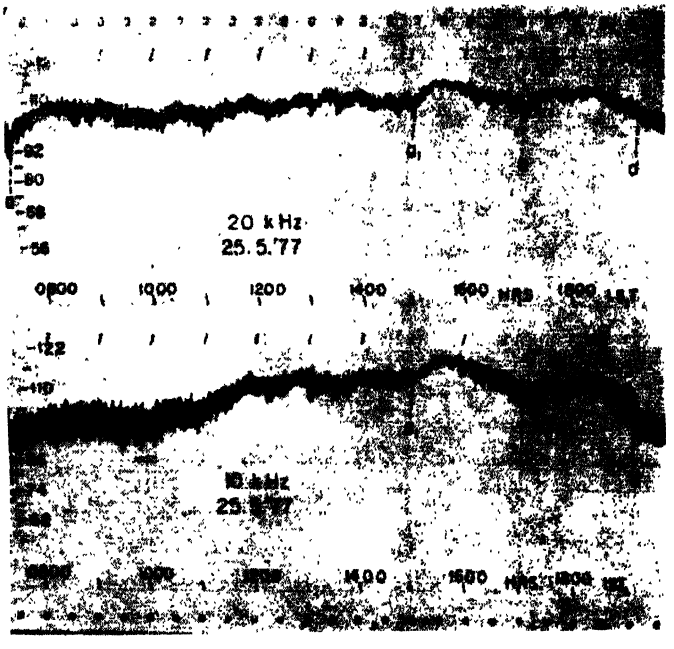

Fig. 1. Typical records of IFIA during a severe Nor'wester over Calcutta. The symbols are : *a*—gradual rise, a_1— first sudden enhancement, *b*- second sudden enhancement, *c*—decay starts, *d*—regaining the normal level. The ordinates are in dB above 1μ v/m.

violent nor'wester observed over Calcutta. The onset time of nor'wester on this particular day was at 1730 hrs (IST). The gradual rise of atmospherics in the records starts at 0733 hrs (IST) while the first and second sudden enhancements occur at 1510 and 1718 hrs (IST) respectively at both the frequencies and the steady recovery of IFIA finally regains the normal night level at 1924 hrs (IST). There is practically no time difference of the starting of different enhancements and that of decay of IFIA at 10 and 20 kHz but the variations of amplitudes indicate a marked difference at the two frequencies.

Detailed features

Our records of IFIA have been analysed with reference to twenty seven thunderstorms observed over Calcutta during the premonsoon period from March to May, 1977. The monthwise distribution is : March-1, April-13 and May-13 and hence it is more frequent in the months of April and May. In table 1, some of the dominant features is given in a summarising form.

Table 1. Dominant features of IFIA at 10 and 20 kHz in relation to premonsoon thunderstorms.

Dominant features	Results
Number of Thunderstorms analysed	27
Number of occurrences of GRA	27
,, ,, ,, ,, SEA_1	27
,, ,, ,, ,, SEA_2	23
In majority of cases (>50%)	
Starting time of GRA	0800–1100 (IST)
,, ,, ,, SEA_1	1230–1700 (,,)
,, ,, ,, SEA_2	1530–1830 (,,)
,, ,, ,, SRA	1830–2300 (,,)
SRA regaining the normal level	2000–0330 (,,)

It is evident from the above table that in general, the initial gradual rise of atmospherics starts in prenoon hours while the first and the second sudden enhancements occur in late noon and afternoon hours of the day respectively.

Histograms of the durations of GRA, SEA_1 and SEA_2 as well as that of the steady recovery time of atmospherics are presented in figure 2, which shows their respective variations in the range of 1–8 hrs, 0–80 mins, 0–40 mins and 30–240 mins with the maxima occurring in the ranges 2–3 hrs, 0–20 mins, 0–10 mins and 60–90 mins respectively. Moreover, the histograms of the time difference between the onset of a nor'wester and the associated GRA, SEA_1 and SEA_2 are given in figure 3, which shows that the GRA and SEA_1 start about 2–12 and 0–9 hrs in advance respectively before the onset of the associated thunderstorm

over the station. But the histogram of the time difference between the onset of the second sudden enhancement and the thunderstorm is highly interesting,

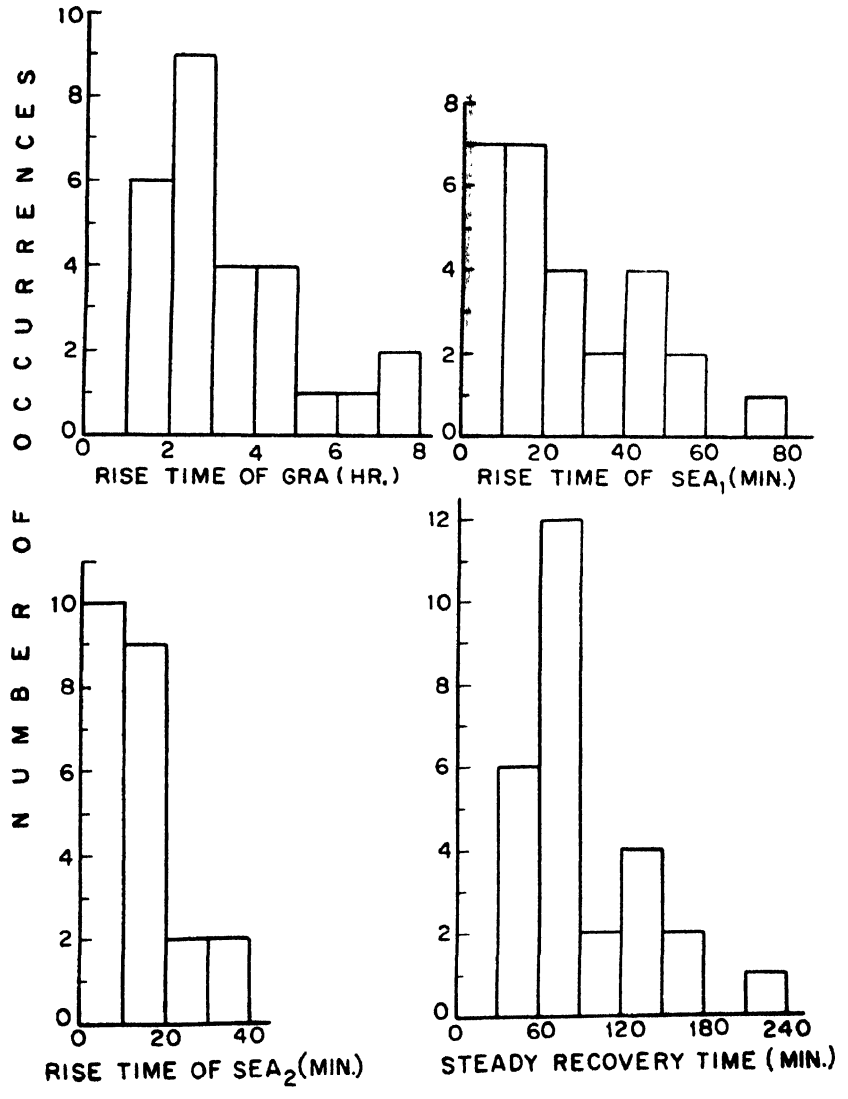

Fig. 2. Histograms of the durations of rise and recovery times of atmospheric associated with premonsoon thunderstorm.

showing the onset of thunderstorm to be earlier than that of SEA_2 for five occasions. In fact, the time advance of GRA, SEA_1 and SEA_2 has a tendency to cluster around 6–7, 2–3 and 0–1 hrs respectively.

A comparative study has also been made of the number of occurrences of GRA, SEA_1, SEA_2 and that of the SRA at the two harmonically related VLF frequencies, 10 and 20 kHz. The results are shown in table 2.

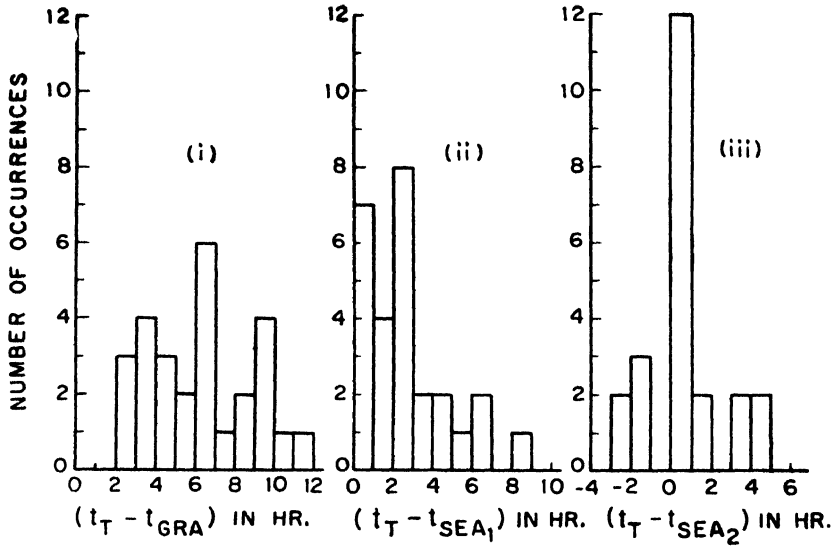

Fig. 3. Histograms of the time difference between the onset time of a thunderstorm (t_T) and that of the (i) gradual rise of atmospherics (t_{GRA}), (ii) first sudden enhancement of atmospherics (t_{SEA_1}) and (iii) second sudden enhancement of atmospherics (t_{SEA_2}).

Table 2 Amplitude distribution in DB over 1μV/M for GRA, SEA_1, SEA_2 and SRA at 10 and 20 kHz.

Nature of variation	Number of occurrences in the following amplitude ranges					
	0–10	10–20	20–30	30–40	40–50	50–60
GRA	4 (11)	7 (9)	6 (2)	6 (2)	3 (3)	1 (–)
SEA_1	4 (11)	13 (12)	4 (2)	3 (1)	2 (1)	1 (–)
SEA_2	6 (12)	6 (9)	7 (2)	4 (–)	– (–)	– (–)
SRA	1 (7)	4 (12)	4 (2)	8 (5)	9 (1)	1 (–)

Number within parenthesis indicates the occurrence at 20 kHz.

It is noticed from the above table that the variatons for more than two-thirds of the cases of the gradual rise and the sudden enhancements (both SEA_1 and SEA_2) lie in the range of 10–40 and 0–30 dB respectively at 10 kHz while

those at 20 kHz lie in the range of 0–20 dB for all type of variations. Similarly the steady recovery of IFIA for majority of the cases has been found to lie in the range 20–50 and 0–20 dB at 10 and 20 kHz respectively.

3. Discussions

Meteorological evidences suggest that premonsoon thunderstorms over Calcutta are the continuations of those occurring earlier in Bihar (Hazaribag area) and in the western part of West Bengal (Asansol and neighbouring areas). Cumulus clouds which are generally of soft fluffy nature sometimes build up to great heights with right conditions of heat and moist air and develop into thunderstorms. If rain begins to fall the clouds are called cumulonimbus, the height of which is decreased with the increasing electrical activity due to vigorous charge separation occurring at that time (Workman & Reynolds 1949, Mull *et al* 1963). The different stages of enhancements in the records of atmospherics may be attributed closely to this process of forming cumulonimbus structure. However, the time delay between the initial gradual rise of IFIA and thunderstorm is easily explainable as it would depend widely on the distance of origin, the degree of development and the rate of movement of the particular thunderstorm towards the observing station.

The initial gradual rise of IFIA is possibly associated with the gradual development of towering cumulus through detached cumulli while the first sudden enhancement of atmospherics appears to be related to the onset of marked instability when the upper level of the towering cumulus reaches the surface of discontinuity (Woikmann 1953). At this stage the height of the cloud is suddenly increased causing an increase of electrical activity which in turn indicates a sudden enhancement in the records of atmospherics.

The second sudden enhancement of atmospherics is most probably due to the vigorous charge separation during precipitation from the cumulonimbus cloud. In fact, for four different cases in the records when no such enhancement was noticed, no rainfall was associated with thunderstorms while for the rest twenty three cases there were always rainfall, thus indicating an intimate relation between SEA_2 and precipitation. The absence of precipitation in four cases appears to be due to an insufficient increase of convection currents resulting a failure of cumulus head to produce dense cumulonimbus clouds. Further, histograms of figure 3 (iii) show that for five occasions the second enhancement and hence the associated precipitation starts after the onset of thunderstorm while for the remaining eighteen occasions their occurrences are reversed. Thus one may conclude that the timing of precipitation in relation to thunderstorm differ considerably from one to another and it can be suitably classified into three heads : (i) rain precede the thunderstorm, (ii) rain follows the thunderstorm and (iii) little or no rain accompanied by thunderstorm.

It has been further found (Table 2) that most of the enhancements at 20 kHz are of relatively lower magnitude while those at 10 kHz are of relatively higher magnitude. Such a behaviour would be expected if the atmospherics due to thunderclouds are presumed to originate from the return strokes for which a peak in the intensity of radiation is known to occur at about 10 kHz (Hill 1957, Kimpara 1965). Earlier study by Khastgir *et al* (1957) over tropical region suggested a vital role of cloud flashes in producing atmospherics. Moreover, it is known that in tropical countries, like India, intra cloud discharges occur for greater than 90% of the cases (Pierce 1962). Our results, therefore, indicate that the spectra of the radiation from cloud flashes would exhibit a distribution in which the intensity at 10 kHz is more than that at 20 kHz.

It may be mentioned finally that the enhancement of IFIA if supplemented by directional observations might prove to be an effective aid in forecasting the violent thunderstorms of premonsoon months for the security of aerial navigation.

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